

# Recycled Water Research

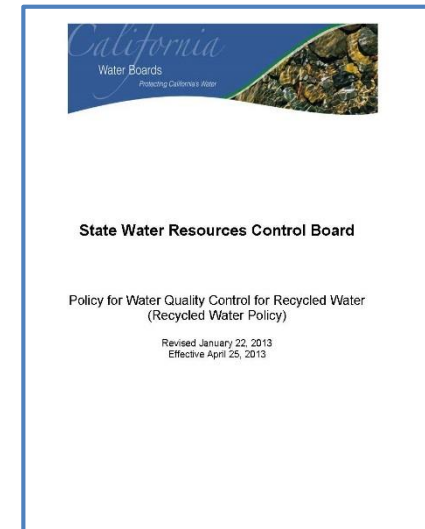


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**Reconvening the Constituents of Emerging Concern  
Science Advisory Panel for Recycled Water  
July 19, 2017  
Costa Mesa, California**

# Presentation Overview

- **Background**
- **Comments on Panel Process**
  - Recycled Water Policy (2009)
  - Previous Panel approach (2010)
  - SWRCB DPR Expert Panel (2016)
  - Sources of information
- **CEC (and Antimicrobial Resistance) Research**
  - WE&RF and Water Research Foundation (Thanks to Alice Fulmer!)
  - Bioanalytical tools



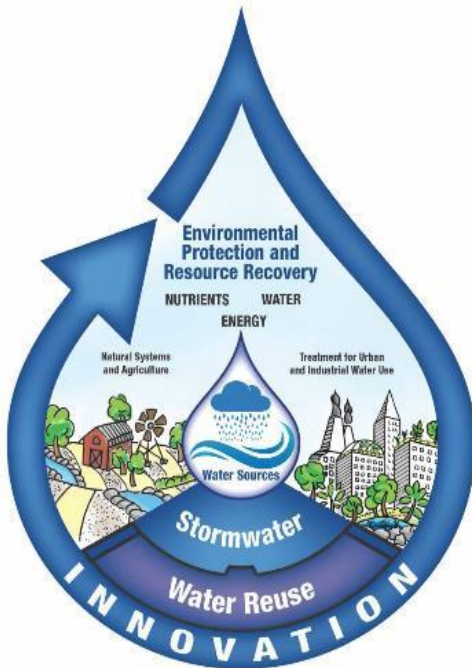


## Water Environment & Research Foundation

**WE&RF:** Dedicated to research on renewable resources from wastewater, recycled water, and stormwater while protecting public health and improving the environment.

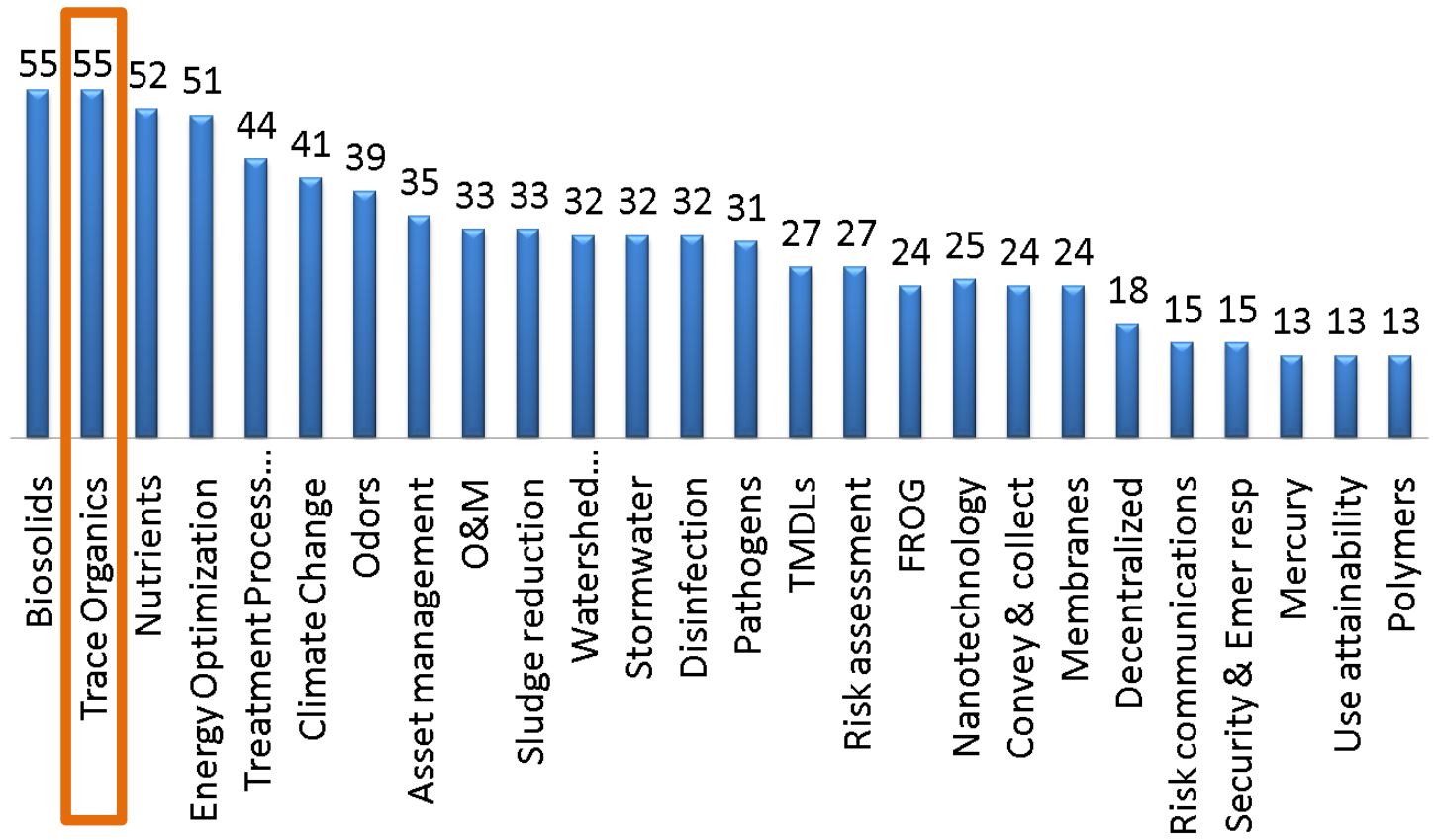
**Merger in 2016 of:**

- Water Environment Research Foundation (WERF)
- WaterReuse Research Foundation

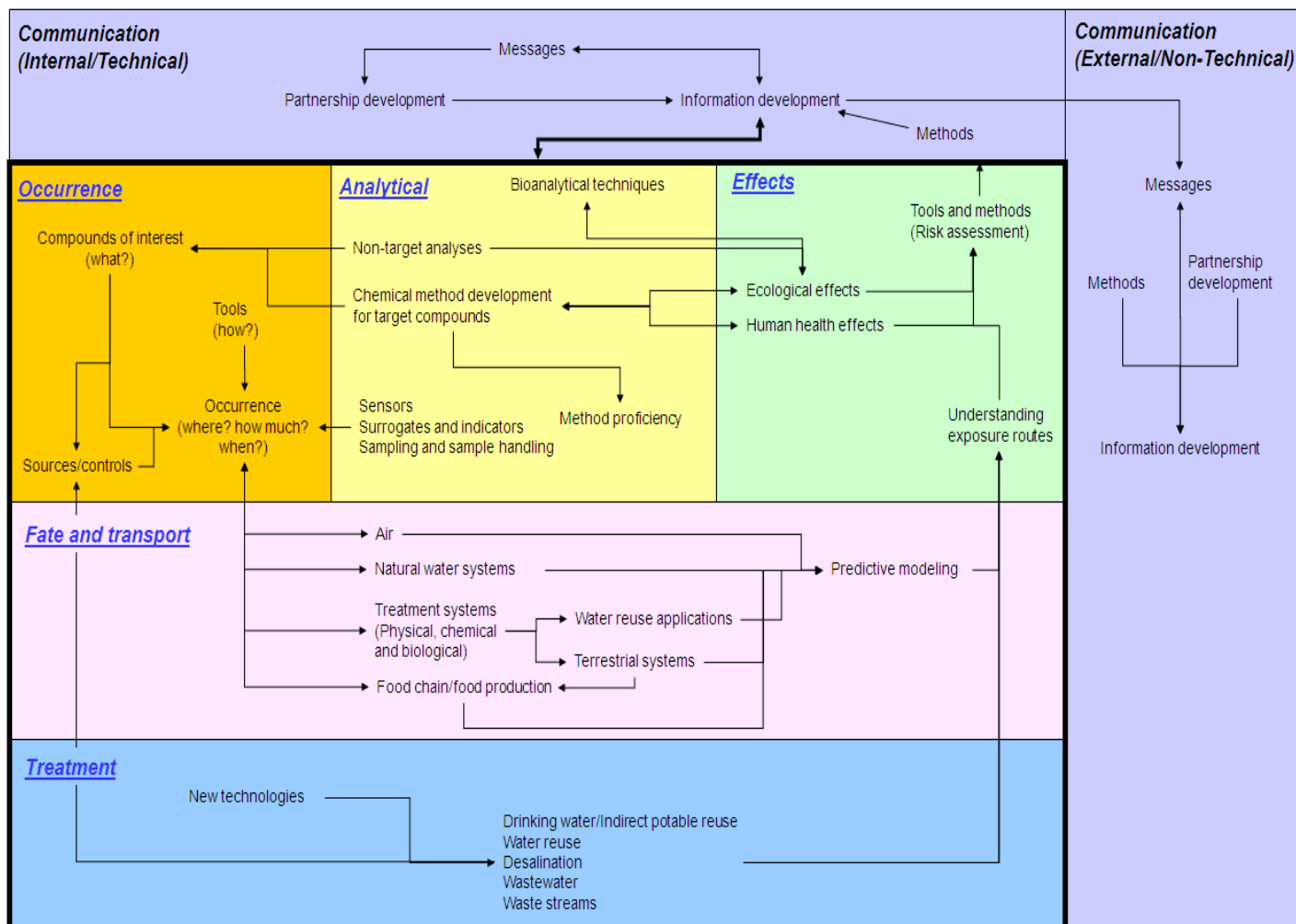


# Survey: Which research topics are the most important for your organization? (WERF 2010)

*The percentage of total respondents selecting that topic*



## RESEARCH ROADMAP ON TRACE ORGANIC COMPOUNDS



**Source:**

**WERF Workshop  
on Trace Organics:  
Mapping a  
Collaborative  
Research roadmap  
(May 2007 in San  
Francisco, CA)**

# Background

## CECs in Recycled Water in CA

- **Recycled Water Policy** (2009) provided support for recycled water
  - Several reasons – including CECs
- **2010 Final Report on Monitoring Strategies on CECs** provided a valuable resource for SWRCB and the recycled water community
- **Recycled Water Policy** (amended in 2013 with CEC monitoring)
  - ATTACHMENT A – Requirements for Monitoring Constituents of Emerging Concern in Recycled Water
  - “Health-based CECs” “performance indicator CECs” – **Useful!**
  - Table 1 – CECs to be Monitored – **Addressed a need!**
  - Effectiveness of unit processes to remove CECs
    - Performance indicator CECs and Surrogates – **Useful!**

# **Comment: Charge to the Panel on CECs in Recycled Water is Appropriate**

- **Questions:**
  - What are the appropriate constituents to be monitored, including analytical methods and method detection limits?
  - What is the known toxicological information for the above constituents?
  - Would the above lists of constituents change based on level of treatment and use including Title 22 applications and surface water augmentation? If so, how?
  - What are possible indicators and surrogate that represent suites of CECs?
  - What levels of CECs should trigger enhanced monitoring of CECs in recycled water, groundwater, and/or surface waters?
- **CECs and ARB/ARG**
- **Recycled water – adding Surface Water Augmentation**
  - Direct Potable Reuse – address separately



# Sources of Information

- **SWRCB DPR Expert Panel Report (2016)**
  - **Section 2.2 Overview of Chemicals of Concern**
    - Sources of health-based benchmarks exist for unregulated constituents
      - WHO Guidelines for Drinking Water Quality
      - U.S. EPA's Drinking Water Health Advisories
    - The use of “Margins of Exposure” (MOEs) applied to scientifically defensible points of departure, can be applied to chemicals
    - “Thresholds of Toxicological Concern,” (TTC) and the related Threshold of Regulation (TOR) are approaches that can be used as means of assessing small concentrations
  - **Chapter 7: Antibiotic Resistant Bacteria and Antibiotic Resistance Genes**

## Potable Reuse and CECs

- **Recycled Water Policy (amended in 2013) monitoring requirements (Tables 3-5)**
  - Groundwater Recharge Reuse - Surface Application
  - Groundwater Recharge Reuse - Subsurface Application
- **Comment:**
  - It would make sense to develop similar requirements for Surface Water Augmentation

## Sources of information (2010 Report)

- **USEPA Candidate Contaminant List 3 (CCL3)** selection process represents a transparent and comprehensive approach – **Agree!**
  - **CCL4** was released by U.S. EPA in 2016
- **“Known knowns”** chemicals that have been previously identified, analytical methods exist for their detection, and measured environmental concentrations (MECs) are available – **Agree!**
- **“Unknown knowns”** compounds (e.g., transformation products) are known to occur but the concentrations have not yet been quantified – **Agree!**
  - **Disinfection by-products or DBPs** (e.g., NDMA)
  - **Comment:** Is a broader consideration of DBPs needed in this review?
- **“Unknown unknowns”** representing chemicals, which presence in is unknown and no analytical methods currently exist – **Agree!**
  - **2010 Report** – suggested bioassays

# WE&RF and Water Research Foundation Research

- WE&RF – List of CEC research projects
- Water Research Foundation – List of CEC research projects



# Cyanobacterial Blooms and Cyanotoxins: Monitoring, Control, and Communication Strategies

By 2022, develop a tool box to help utilities  
prepare for cyanobacterial blooms, by developing  
**cost-effective control strategies** and  
**risk communication approaches**



# Non-Regulated DBPs in Drinking Water: Occurrence, Toxicological Relevance, and Control Strategies

By 2022, develop resources to inform regulators and assist utility compliance with regulations by understanding the **occurrence**, **precursors**, **health effects**, and **control strategies** of non-regulated DBPs.

# NDMA and Nitrosamines

## Focus Area Objectives



### Investigate the contribution of

- source water quality
- treatment processes
- distribution system operations



### Develop control strategies to prevent or minimize the formation of nitrosamines



### Identify unintended consequences and cost of implementation

# Hospital Wastewater Practices and CECs in Water (WRF #4616)

Ruth Marfil-Vega, American Water  
Shelley Ehrlich, CCHMC  
Marc A. Mills, US EPA ORD







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# **TREATMENT MITIGATION STRATEGIES FOR POLY- AND PERFLUOROALKYL AND POLYFLUORINATED CHEMICALS**

**WRF #4322**

advancing the science of water

# WRRF 11-02 (Trussell Technologies)

## Monitoring Locations: Secondary Effluent and Tertiary Effluent



- **Secondary Effluent**

- **Six Facilities:**

- The San Jose Creek WRP, Whittier, CA (4 samples)
    - The North City WRP, San Diego, CA (12 samples)
    - The Fred Hervey WRP, El Paso, TX (4 samples)
    - The Millard Robbins, WRP, Centerville, VA (4 samples)
    - OCSD Plant No. 2, Fountain Valley, CA (1 sample)
    - The Hyperion WRP, Los Angeles, CA (1 sample)

- **Total 26 samples**, 24 samples were measured by Snyder et al.

- Looked at 42 CECs
  - 39 were detected at least once
  - 11 were detected in all samples
  - 14 additional were detected in majority samples

- **Tertiary Effluent**

- **Two Facilities:**

- West Basin Municipal Water District, CA (3 samples)
    - Orange County Water District, CA (1 sample)

- **Total 4 samples**

- Looked at 37 CECs
  - 32 were detected at least once
  - 12 were detected in all samples
  - 13 additional were detected in majority samples

# CEC Occurrence (WRRF 11-02)

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## Detected in Secondary (39)

Acesulfame K, Atenolol, Carbamazepine, DEET,  
Diphenhydramine, Iohexol, Iopamidol, Perfluorohexanoic  
acid (PFHxA), Sucralose, Sulfamethoxazole, TCPP  
Caffeine, Diclofenac, Diltiazem, Fluoxetine, Gemfibrozil,  
Ibuprofen, Meprobamate, PFOA, Primidone, Simazine,  
TCEP, Triclocarban, Triclosan, Trimethoprim  
Atrazine, Benzophenone, Benzotriazole, Bisphenol A,  
Clofibric Acid, Dexamethasone, Estrone, Hydrocortisone,  
Iopromide, Naproxen, Norgestrol, Perfluorobutyric acid  
(PFBA), PFOS, Testosterone

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## Detected in Tertiary (31)

Atenolol, Caffeine, Carbamazepine, DEET,  
Gemfibrozil, Ibuprofen, Naproxen, Primidone,  
Sulfamethoxazole, TCEP, Triclosan, Trimethoprim  
Acesulfame-K, Benzophenone, Benzotriazole,  
Diphenhydramine, Diltiazem, Hydrochlorothiazide,  
Iohexol, Iopamidol, Iopromide, PFBA, PFOA,  
Sucralose, Triclocarban  
Atrazine, Diclofenac, Estrone, Fluoxetine,  
Meprobamate, Simazine

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Detected in all samples

Detected in majority of samples

Detected at least once

## CEC Removal by RO

- Data Origin: **Trussell et al., WRRF 11-02**
- Advance Water Treatment Facilities:
  - West Basin Municipal Water District, CA (3 samples)
  - Orange County Water District, CA (1 sample)
- Looked at 37 CECs
- 32 were detected in tertiary effluent
- 10 were detected in RO permeate

# CEC Removal by RO

Excellent Removal		Fair Removal	Poor Removal
Reduced to ND	Removal > 90%	50 to 90%	<50%
Atenolol, Atrazine, Carbamazepine, Diclofenac, Estrone, Fluoxetine, Gemfibrozil, Hydrochlorothiazide, Ibuprofen, Iopamidol, Meprobamate, Naproxen, Primidone, Simazine, Sulfamethoxazole, Triclocarban, Trimethoprim	Acesulfame-K, Sucralose, DEET, Triclosan	Benzophenone, Iopromide, PFOA	Benzotriazole
TCEP			
		NDMA	
Caffeine, Iohexal			

## CEC Removal by O3/BAC

- Data Origin: **Trussell et al., WRRF 11-02**
- Advance Water Treatment Facilities:
  - Fred Hervey Water Reclamation Plant, El Paso, TX (4 samples)
  - The San Jose Creek WRP, Whittier, CA (Pilot) (4 samples)

# CEC Removal by O3/BAC

Excellent Removal		Fair Removal	Poor Removal
Reduced to ND	Removal > 90%	50 to 90%	<50%
Diphenhydramine, Ditiazem, Estrone, Fluoxetine, Gemfibrozil, Ibuprofen, Naproxen, Testosterone, Triclosan, Trimethoprim		Benzotriazole	PFOS, Sucralose
Acesulfame K, Atrazine, Bisphenol A, DEET, Iopromide, PFHxA, PFOA, TCEP			
Atenolol, Benzophenone, Caffeine, Carbamazepine, Hydrocortisone, Primidone, Simazine			
Diclofenac, Sulfamethoxazole, Triclocarban			
Iohexol, Iopamidol, Meprobamate, <b>NDMA</b> , TCP			

# CEC Removal by Soil Aquifer Treatment (SAT)

- Data Origin: **Trussell et al., WRRF 12-12;**  
**Trussell et al., WRF 4600**



# CEC Removal by SAT

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Excellent Removal  
(>90%)

Fair Removal  
(90 to 50%)

Poor Removal  
(50 to <25%)

Atenolol, Atorvastin, BHA, Caffeine,  
Dioctyl phthalate, Enalapril,  
Fluoxetine, Galaxolide, Nonylphenol,  
Norfluoxetine, Salicylic acid,  
Simvastatin hydroxy acid,  
Trimethoprim

Carbamazepine, Primidone, TDCPP

Benzophenone, Ibuprofen, DEET, EDTA, Iopromide, Meprobamate, Sulfamethoxazole

Diclofenac, Naproxen, Gemfibrozil, Octylphenol, Tonalide, Triclosan

Dilantin (Phenytoin), TCEP, TCPP

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Data origin: Drewes et al., WRRF 05-04, travel time up to 2 weeks

# Direct Potable Reuse: Lessons from Big Spring, Texas (Texas Water Development Board and WE&RF 14-10)

Eva Steinle-Darling, PhD, PE

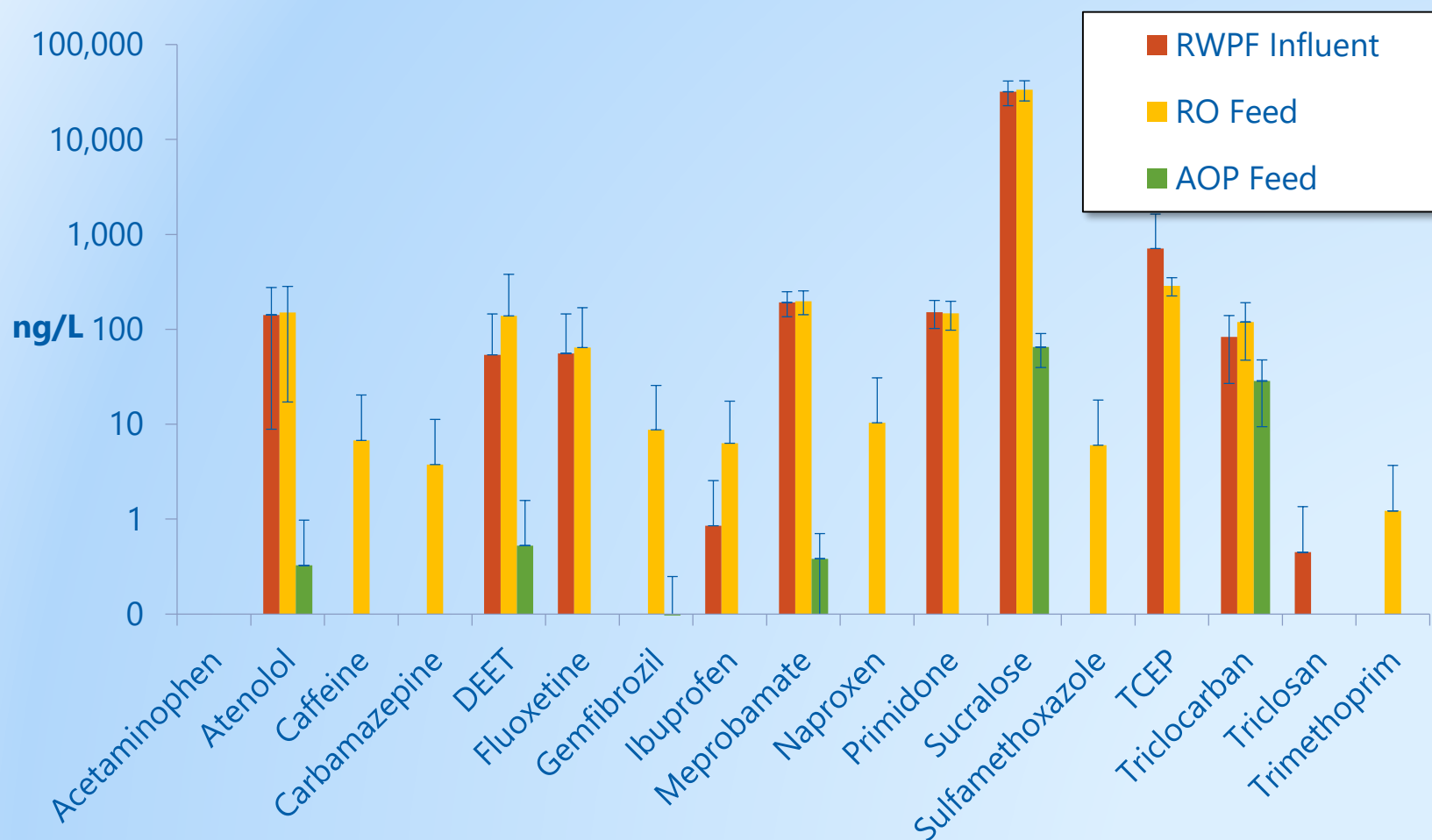
2017 New Mexico Water  
April 21, 2017

Albuquerque

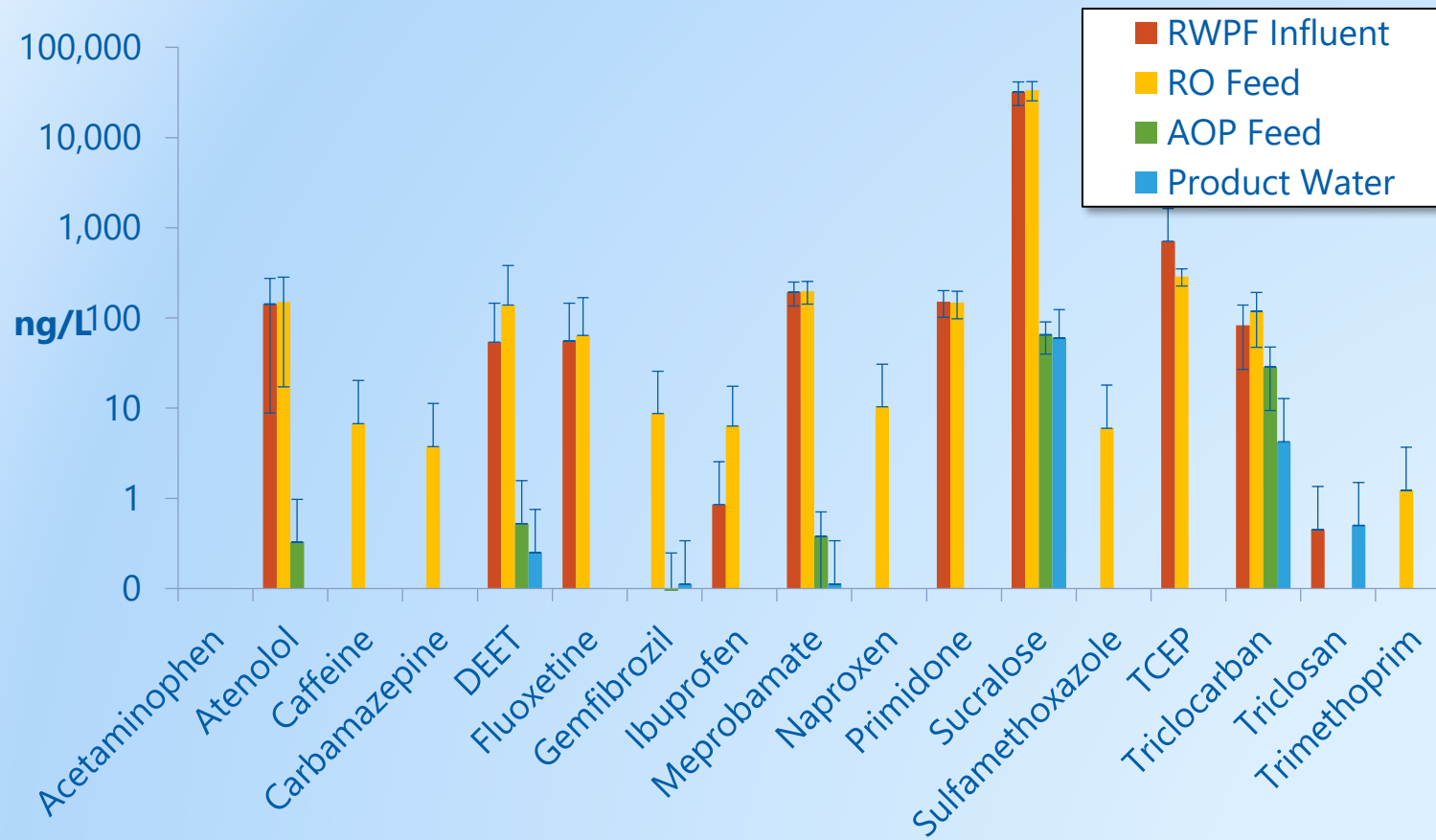
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## Big Spring, TX: RO Achieves Robust Removal of Trace Organics



# Big Spring, TX: After UV Advanced Oxidation





# Project Updates WRF 4536/WE&RF 13-15 Altamonte Springs FL DPR Demonstration

July 2017

Andy Salveson

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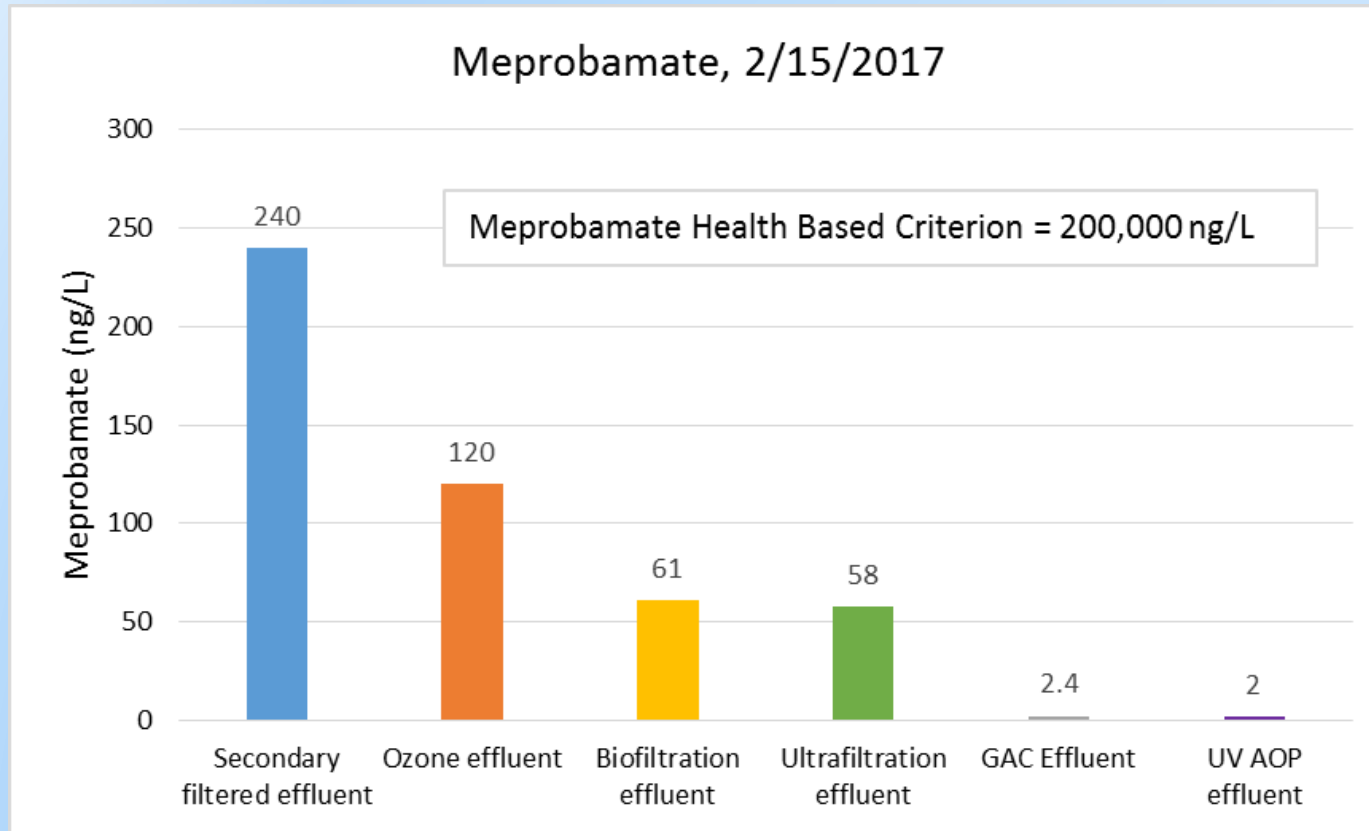
# Altamonte Springs FL DPR Demonstration



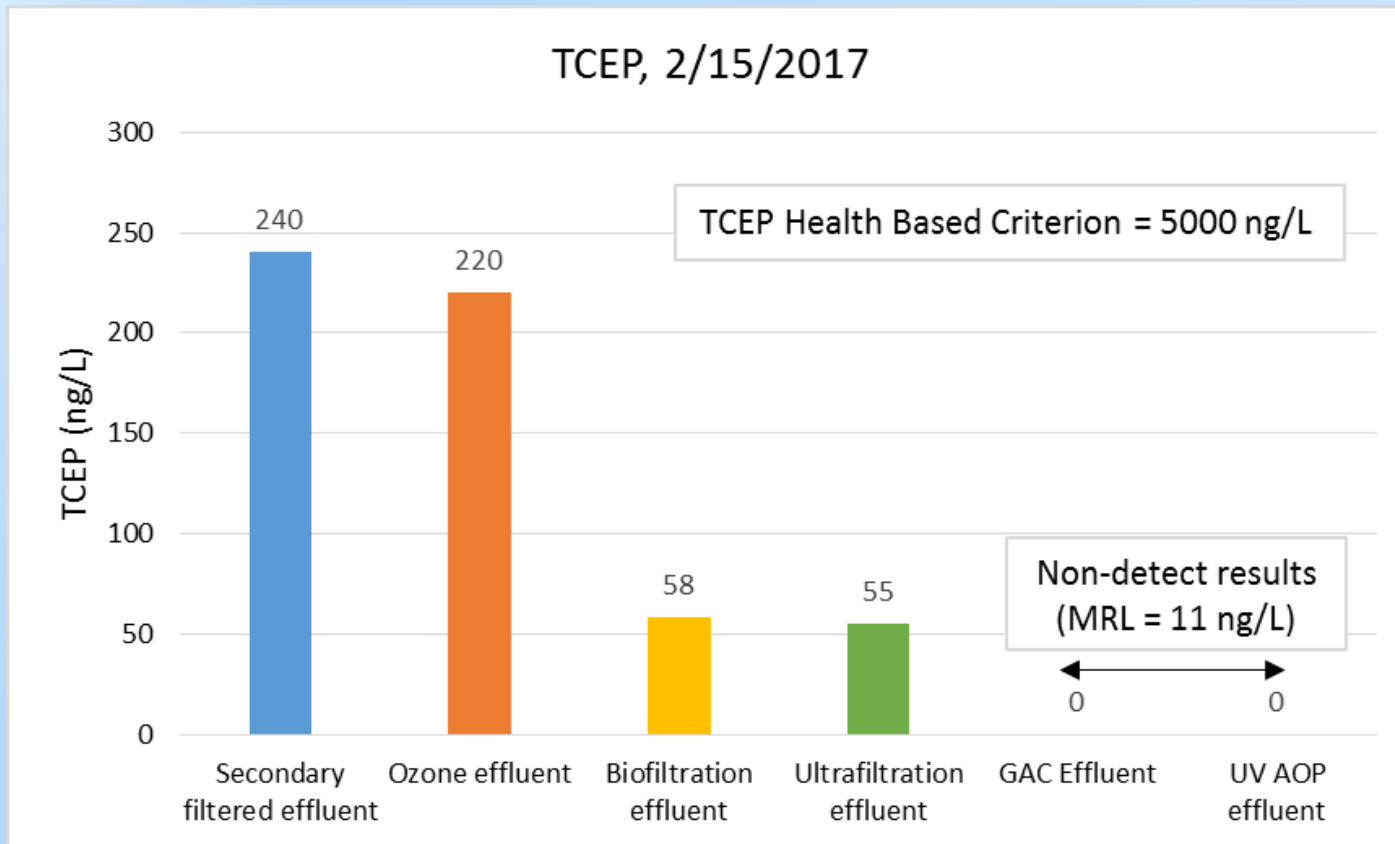
Sample Point



## CECs are removed through the pilot to provide a polished product water

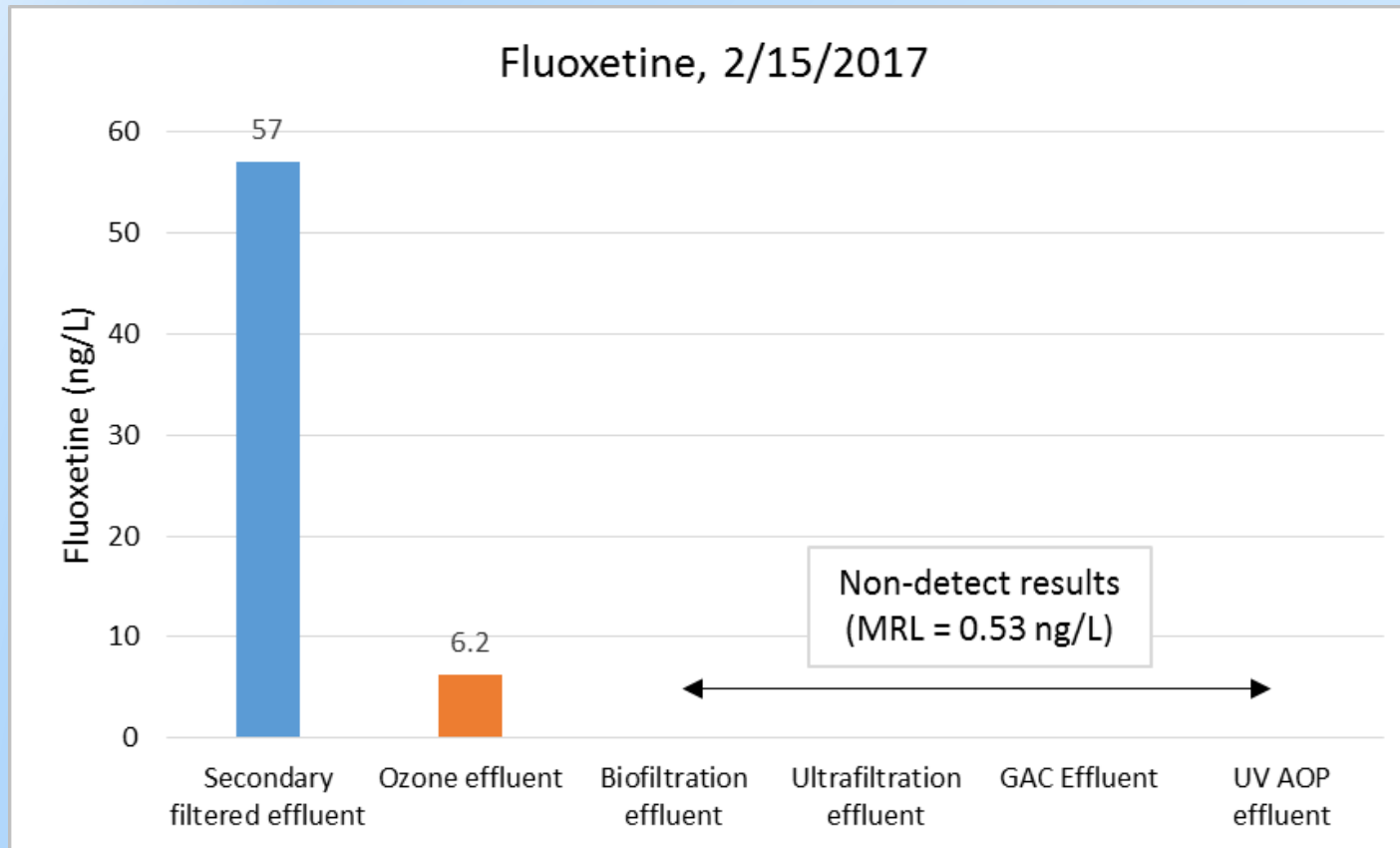


## CECs are removed through the pilot to provide a polished product water

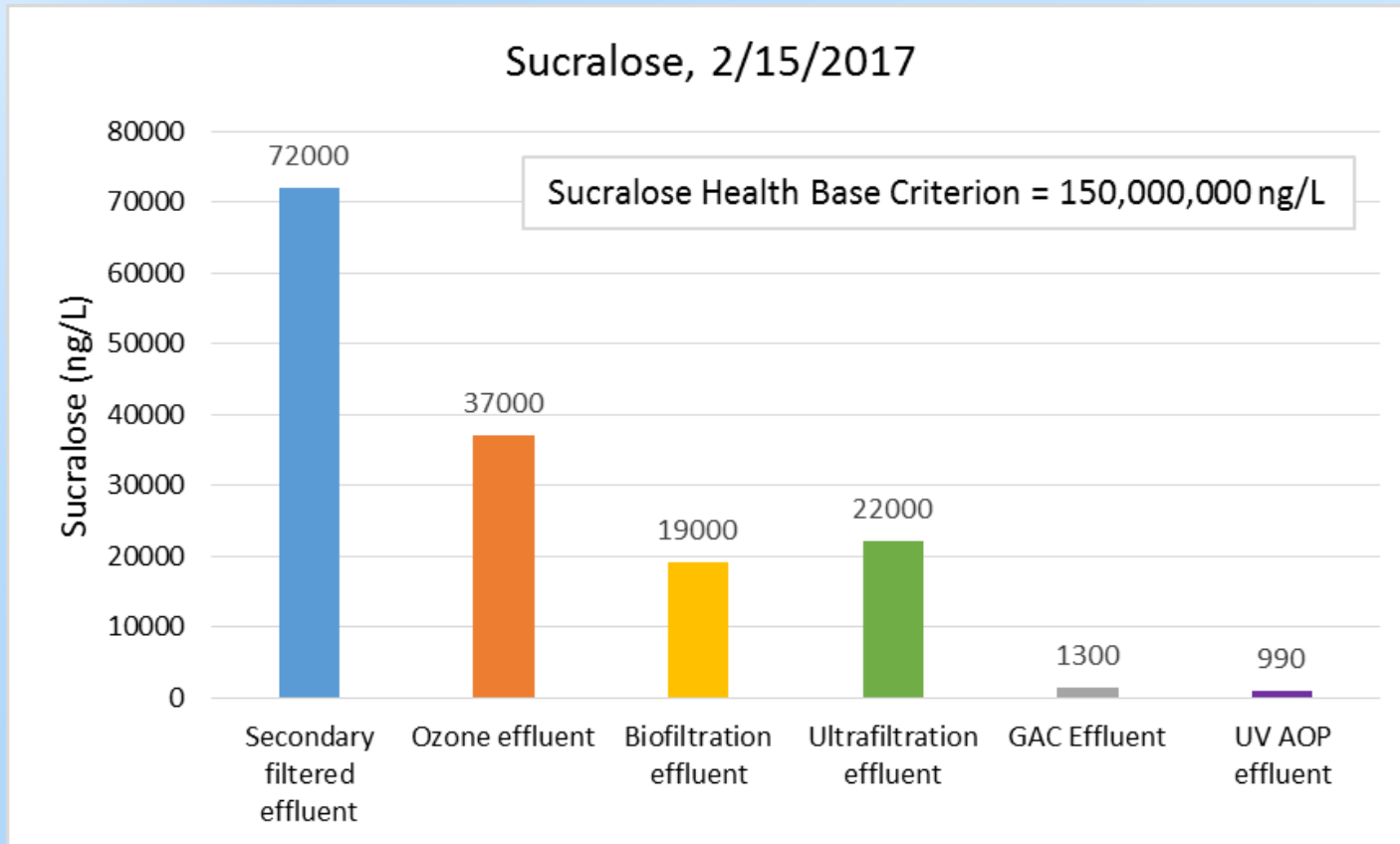




## CECs are removed through the pilot to provide a polished product water



## CECs are removed through the pilot to provide a polished product water



# Antimicrobial Resistance

## **SWRCB DPR Expert Panel Report (2016):**

- Chapter 7: Antibiotic Resistant Bacteria and Antibiotic Resistance Genes

# Project Updates WRF 4536

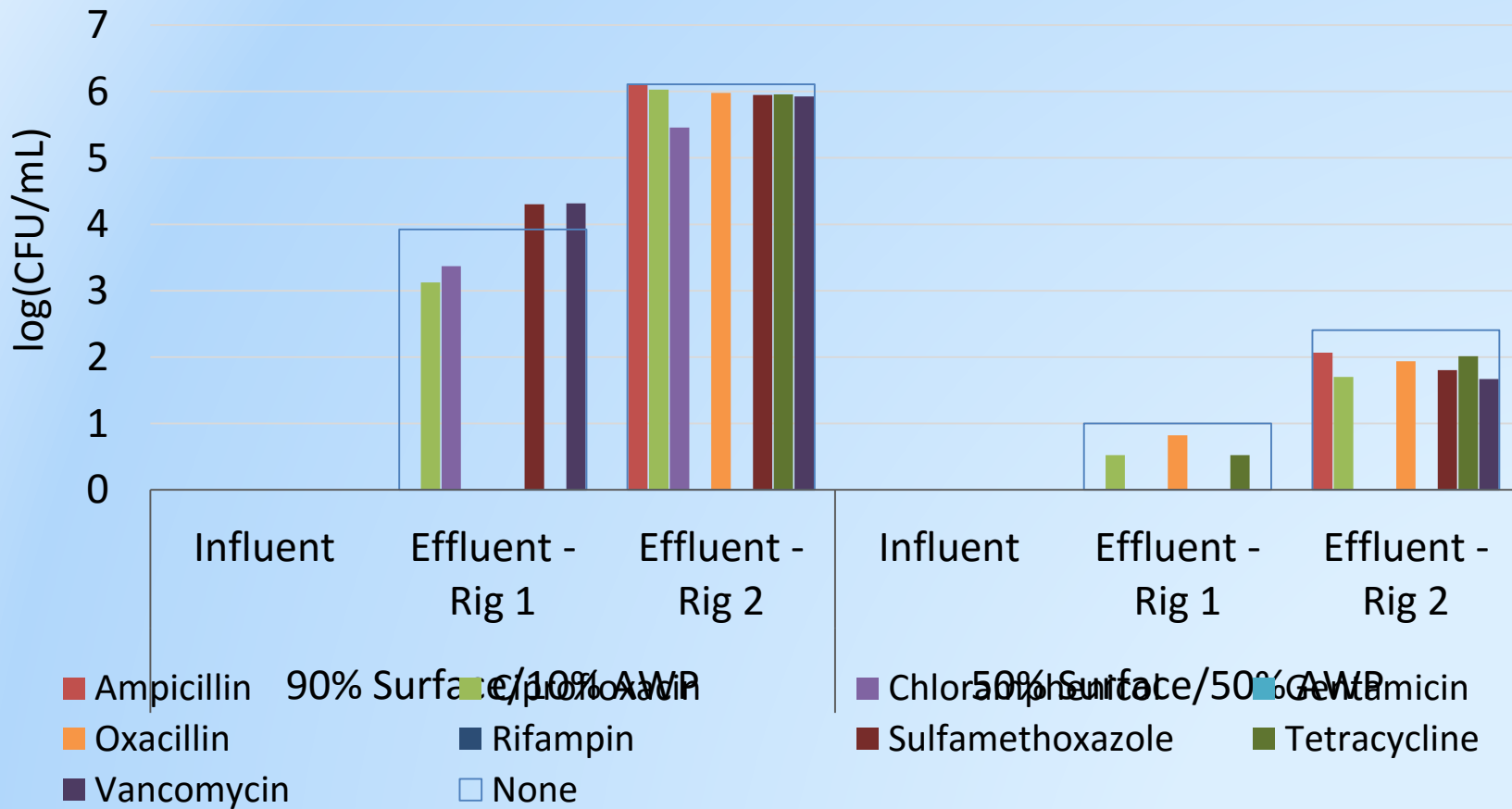
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# Blends of AWP Water Reduced Regrowth of AR HPCs



# Bioanalytical Tools

## Drivers for bioanalytical tools in the US

- Current chemical monitoring **do not address the full range of chemicals** that could occur in water sources and recycled water
  - Including **unknown chemicals**
  - Including **transformation products**
- A California State Water Board Science Advisory Panel **recommended monitoring strategies for chemicals** of emerging concern in recycled water
- Water industry needs **tools to assess chemicals** and their potential human health impact
- Regulatory agencies would like a **framework for evaluating potential biological responses to unknown mixtures of low levels of chemicals** – including for potable reuse

# Potable Reuse Monitoring: What is Unknown?

(Needs for additional research and development)

- Existing monitoring technology is **adequate** to determine the integrity and efficacy of advanced treatment processes
- However, **improvements in monitoring technology** can:
  - Increase confidence in **treatment performance**
  - Inform **regulations**
  - Enhance **public acceptance**
- **Bioanalytical Tools** for potable reuse can:
  - **Supplement** current monitoring practices
  - Provide **comprehensive results for whole classes of water quality risk factors** rather than individual chemical compounds



# Project Updates WRF 4536/WE&RF 13-15 Altamonte Springs FL DPR Demonstration

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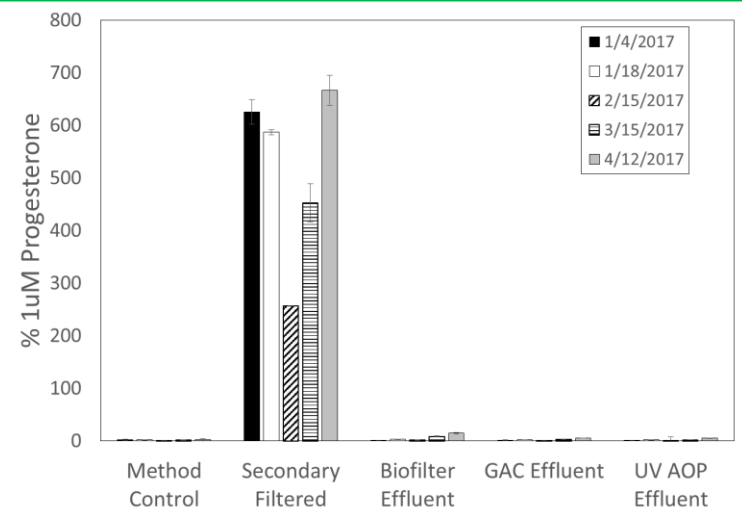
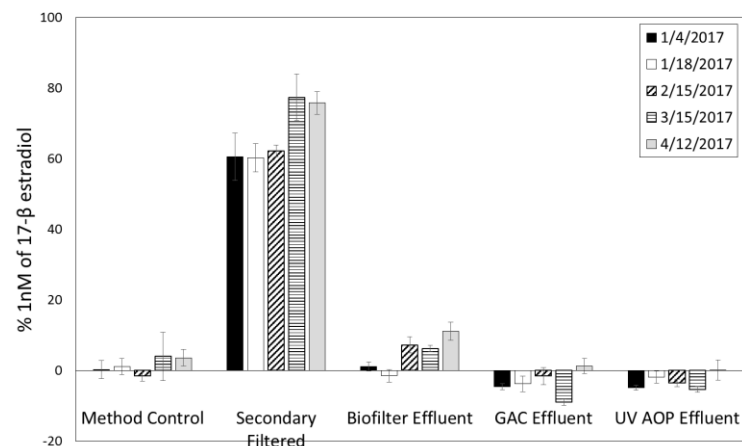
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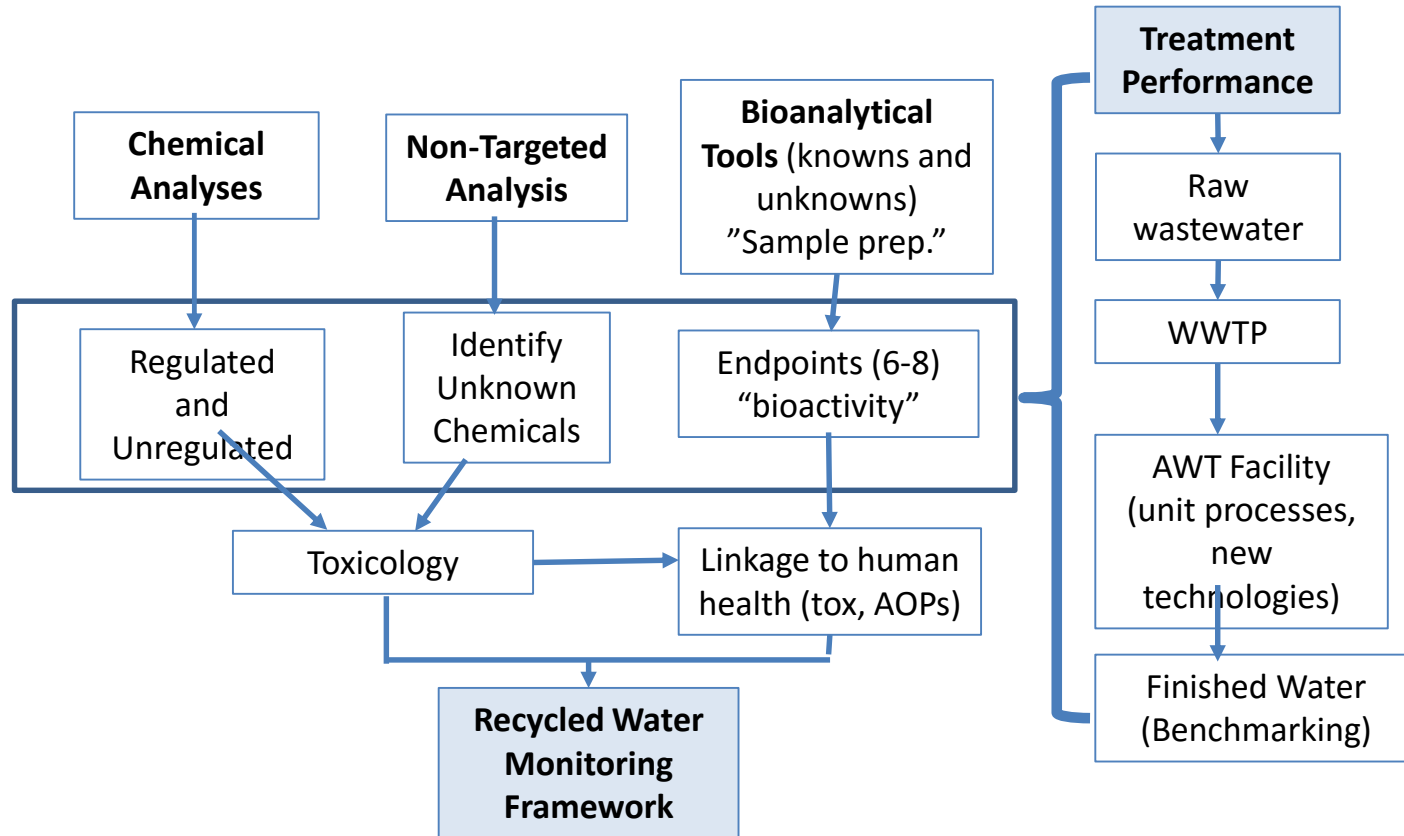
Bioassays indicate bioactivity of hormones/drugs is eliminated through the pilot processes

- **Estrogen like chemicals**
- **Glucocorticoid/ progesterone like chemicals**
- Androgen like chemicals
- Dioxin like chemicals
- Genotoxicity
- Cytotoxicity

Performed by Michael Dennison  
(UC Davis)



# Bioanalytical Tools for Recycled Water Monitoring (specifically potable reuse)



## Next Step: Proposed Research Project “Reuse 17-02”

### Task 1

- Define goals for bioanalytical tool toolbox relative to ambient monitoring and recycled water.

### Task 2

- Develop candidate list of most relevant/ready bioanalytical tool endpoints.

### Task 3

- Compare, optimize and standardize water extraction protocols for chemicals of concern.

### Task 4

- Optimize and standardize selected bioanalytical tools.

### Task 5

- Inter-lab round robin testing.

Estimated Duration: 3 years

Estimated Budget: \$1,500,000+

Collaborators:

- State Water Resources Control Board of California
- **Southern California Coastal Water Research Project**
- WE&RF
- Water Research Foundation
- **Metropolitan Water District of Southern California**
- **University of Arizona**
- **University of Florida**
- **University of California, Riverside**
- **University of California, Davis**

# Final Comments

- **Recycled Water Policy on CECs – Good Policy!**
  - Monitoring lists for human health and for performance
- **Current Panel Charge – appropriate!**
  - CECs, AR, and Title 22, including Surface Water Augmentation
- **WE&RF and WaterRF**
  - Strong interest in recycled water and CEC research
  - SWRCB Prop 1 Grant on recycled water research (Approved June 6)
- **Bioanalytical Tools Research – Underway**
  - But also use non-targeted chemical analysis
- **Specific questions**
  - Disinfection by-products – more attention?
  - Non-RO treatment trains
    - Role of TOC
  - Address DPR addressed through additional research and rule development

# Thank you for listening!

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